

# **EXHIBIT 47**

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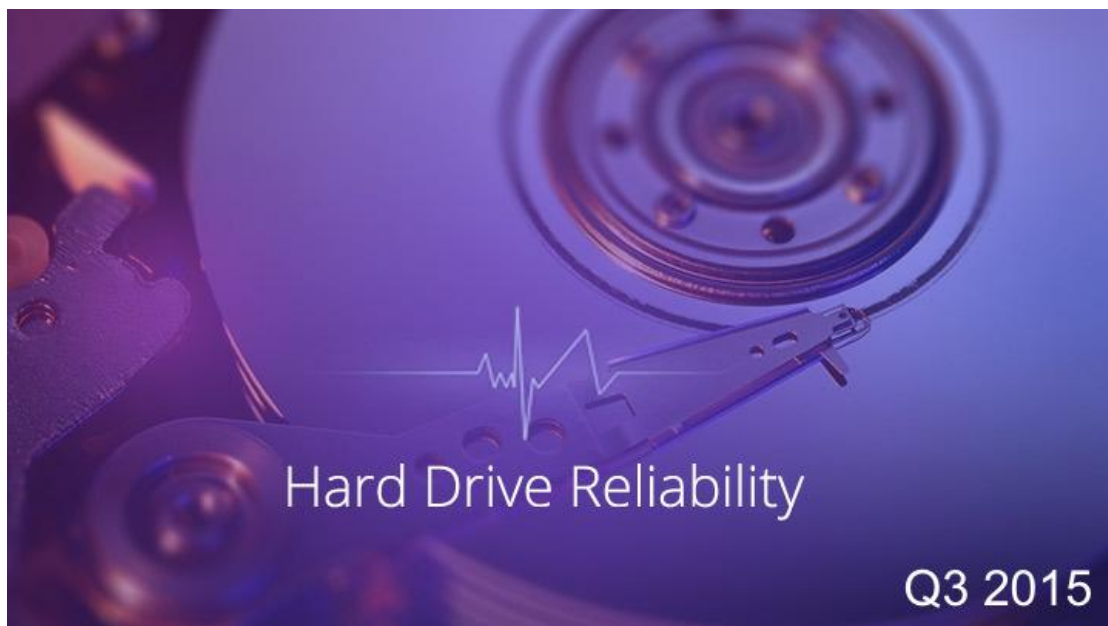
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# What Can 49,056 Hard Drives Tell Us? Hard Drive Reliability Stats for Q3 2015

By [Andy Klein](#) | October 14th, 2015



For the most recent *Hard Drive Reliability Statistics*, as well as the raw hard drive test data, visit [Hard Drive Data and Stats](#).

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Subtracting boot drives, drive models with less than 45 drives and drives in testing systems, we are publishing data on 49,056 hard drives spread across 26 different models, varying from 1.0TB to 8.0TB in size.

## What's New for the Q3 2015 Results?

In this edition, we are publishing the data on our 1TB drives for the first time. The data was always available in the data files we publish on our [Hard Drive Data](#) web page, but now we're reporting the data here too. We are also going to include "Average Drive Age" for each model and we'll summarize the data by manufacturer size as well.

## Hard Drive Failure Rates

Let's start by breaking down the drives by size and comparing them over time:


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Model Name/Number	Size	Rate	Rate	Rate	Rate	Rate	Rate	Rate	Service	(Months)
Western Digital Caviar Green (WD10EACS)	1TB	0.00%	5.21%	0.00%	2.48%	1.40%	8.10%		84	70.5
Western Digital Caviar Green (WD10EADS)	1TB	4.29%	3.90%	9.91%	5.44%	4.10%	7.10%		474	70.0
All 1TB Drives		4.29%	4.09%	8.66%	5.02%					
Seagate Barracuda Green ST1500DL003	1.5TB	129.88%	66.01%	222.77%	106.52%	85.70%	130.90%		51	26.7
Seagate Barracuda 7200.11 (ST31500341AS)	1.5TB	23.29%	23.53%	26.69%	23.87%	20.80%	27.30%		539	67.9
Seagate Barracuda LP (ST31500541AS)	1.5TB	10.52%	9.52%	12.07%	10.43%	9.40%	11.50%		1,929	65.0
All 1.5TB Drives		16.57%	13.11%	15.10%	14.71%					
HGST(*) Deskstar 7K2000 (HDS722020ALA330)	2TB	1.03%	1.07%	2.81%	1.61%	1.40%	1.90%		4,716	55.5
Seagate Barracuda LP (ST32000542AS)	2TB	7.90%	13.43%		10.28%	6.90%	14.20%		288	0.0
Western Digital Red (WD20EFRX)	2TB		0.00%	6.85%	6.85%	2.40%	17.50%		126	6.1
All 2TB Drives		1.45%	1.42%	2.87%	1.88%					
HGST(*) Deskstar 5K3000 (HDS5C3030ALA630)	3TB	0.99%	0.59%	1.31%	0.92%	0.70%	1.10%		4,595	40.5
HGST(*) Deskstar 7K3000 (HDS723030ALA640)	3TB	1.01%	2.27%	2.12%	1.91%	1.40%	2.60%		1,027	45.7
Seagate Barracuda 7200.14 (ST3000DM001)	3TB	10.35%	43.08%	30.94%	28.46%	26.90%	29.60%		4,247	34.5
Seagate Barracuda XT (ST33000651AS)	3TB	6.91%	4.80%	3.55%	5.11%	3.50%	7.30%		293	42.8
Toshiba DT01ACA Series (TOSHIBA DT01ACA300)	3TB	6.93%	3.68%	2.80%	4.20%	1.40%	9.80%		58	29.1
Western Digital Red 3 TB (WDC WD30EFRX)	3TB	3.79%	6.94%	8.79%	7.65%	6.40%	9.30%		1,085	16.3
Western Digital Green 3 TB (WDC WD30EZRX)	3TB	6.32%	0.00%		6.32%	4.10%	9.80%		388	0.0
All 3TB Drives		5.22%	15.06%	4.33%	9.43%					
HGST(*) Deskstar 5K4000 (HDS5C4040ALE630)	4TB	1.65%	0.91%	0.86%	1.07%	0.80%	1.40%		2,643	29.9
HGST Megascale 4000 (HMS5C4040ALE640)	4TB	3.85%	1.41%	0.70%	0.93%	0.70%	1.20%		7,092	14.0
HGST Megascale 4000.B (HMS5C4040BLE640)	4TB		0.52%	0.47%	0.50%	0.30%	0.80%		3,103	16.9
Seagate Desktop HDD.15 (ST4000DM000)	4TB	4.17%	2.58%	3.31%	3.06%	2.80%	3.30%		20,921	13.1
Seagate Barracuda XT (ST4000DX000)	4TB	1.12%	1.12%	3.73%	1.99%	0.70%	3.60%		214	23.8
Toshiba MD04ABA-V Series (MD04ABA400V)	4TB			4.80%	4.80%	1.00%	14.20%		145	5.2
Western Digital Red 4 TB (WD40EFRX)	4TB		0.00%	2.97%	1.42%	0.00%	7.90%		45	18.5
All 4TB Drives		2.75%	1.88%	2.18%	2.10%					
Toshiba MD04ABA-V Series (MD04ABA500V)	5TB			3.84%	3.84%	0.10%	21.60%		45	7.0
All 5TB Drives				3.84%	3.84%					
Seagate 6 TB SATA 3.5 (ST6000DX000)	6TB		0.00%	2.90%	2.84%	1.60%	3.80%		1,882	6.2
Western Digital Red 6 TB (WD60EFRX)	6TB		3.07%	5.73%	5.49%	3.20%	8.20%		458	9.4
All 6TB Drives			2.00%	3.64%	3.58%					
HGST Ultrastar He8 (H11H7280R0A1 F600)	8TB			3.41%	3.41%	0.10%	19.10%		45	7.7



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There's a lot going on in the chart above, here are a few things to help out:

- The 2013, 2014, and 2015 failure rates are cumulative for the given year. In the case of 2015 that is through Q3 (September).
- If the failure rate is listed as 0.00% there were drives in use, but none of the drives failed during that period.
- If the failure rate is blank, there were no drives in use during that period.
- The "All Periods" failure rates are cumulative for all data (2013-Q3 2015).
- The "Max # in Service" column is the maximum number of drives ever in service for the given hard drive model.
- The "Avg Age (Months)" column is the average age of all the hard drives of the given hard drive model. This is based on SMART 9 data.
- If the "Avg Age (Months)" data is 0.0, the given drive model was not in service during 2015 making the value difficult to compute. (We'll try to figure out a better way to compute this value by the next report.)
- The HGST (\*) model name – we've been asked to use HGST in place of Hitachi and we are honoring that request, but these drives report their model as Hitachi and are listed as such in the data files.
- The Low Rate and High Rate are the boundaries for the confidence interval for the failure rate listed.

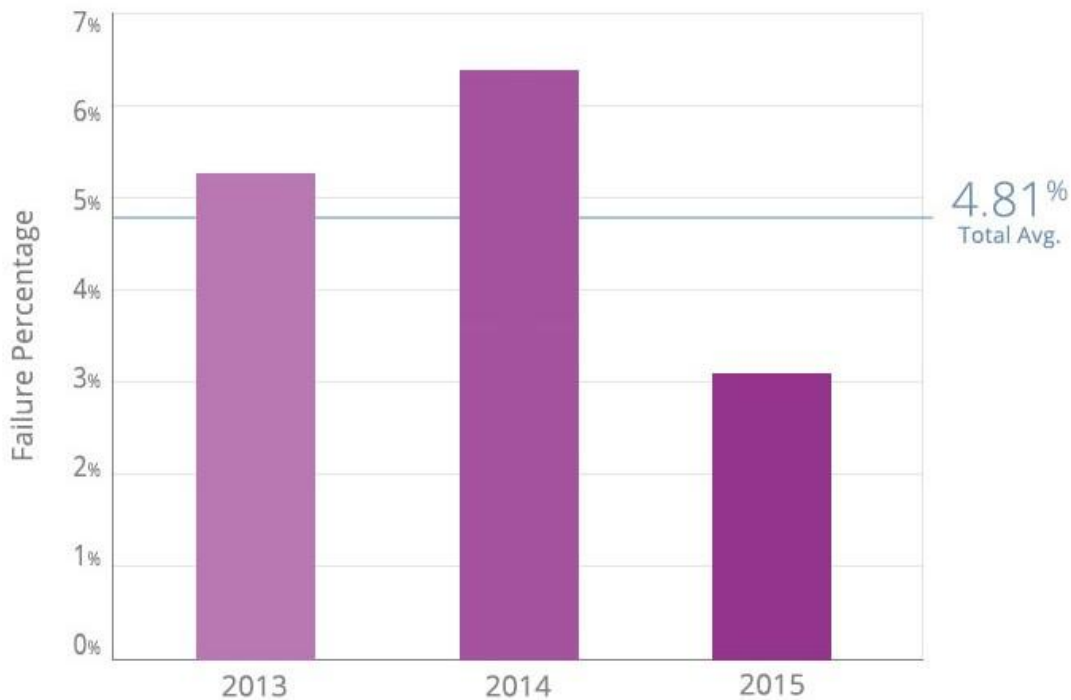
If the chart is too much data all at once, you can [download a ZIP file](#) that when unzipped contains a Microsoft Excel file of the data from the chart. Then you can parse the facts and figures at your leisure.

### Some Observations Based on This Data



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drives at 4.81%.

## Hard Drive Failure Rates. All Drives. All Manufacturers. (Year 2013-2015)



- The Western Digital 1TB drives in use are nearly 6 years old on average. There are several drives with nearly 7 years of service. It wasn't until 2015 that the failure rate rose above the annual average for all drives. This makes sense given [the "bathtub" curve of drive failure](#) where drives over 4 years start to fail at a higher rate. Still the WD 1TB drives have performed well for a long time.
- Nearly all of the 1TB and 1.5TB drives were installed in Storage Pod 1.0 chassis. Yet, these two sizes have very different failure rates.



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- Always consider the number of drives (Max # in Service) when looking at the failure rate. For example, the 1.5TB Seagate Barracuda Green drive has a failure rate of 130.9%, but that is based on only 51 drives. We tested these Seagate drives in one Storage Pod in our environment and they were not a good fit. In general, we've found it takes at least 6 Storage Pods (270 drives) worth of drives to get good sense of how a given drive will perform in our environment.
- 4TB drives, regardless of their manufacturer, are performing well. The 2.10% overall failure rate means that over the course of a year, we have to replace only one drive in a Storage Pod filled with these drives. In other words, on average, a pod comes down for maintenance once a year due to drive failure. The math: 2% is 1 out of 50. There are 45 drives in a pod, so about once a year, one of those 45 drives, on average, will fail. Yes, the math is approximate, but you get the idea.
- 6TB drives, especially the Seagate drives, are also performing well, on par with the 4TB drives so far. The 6TB drives give us 270TB Storage Pods, giving us 50% more storage at the same overall cost per GB.
- The 5TB and 8TB drives are performing well, but we only have 45 of each in testing, not enough to feel confident in the numbers yet as can be seen in the confidence interval (low rate/high rate) of these drives.

## Drive Failures by Manufacturer

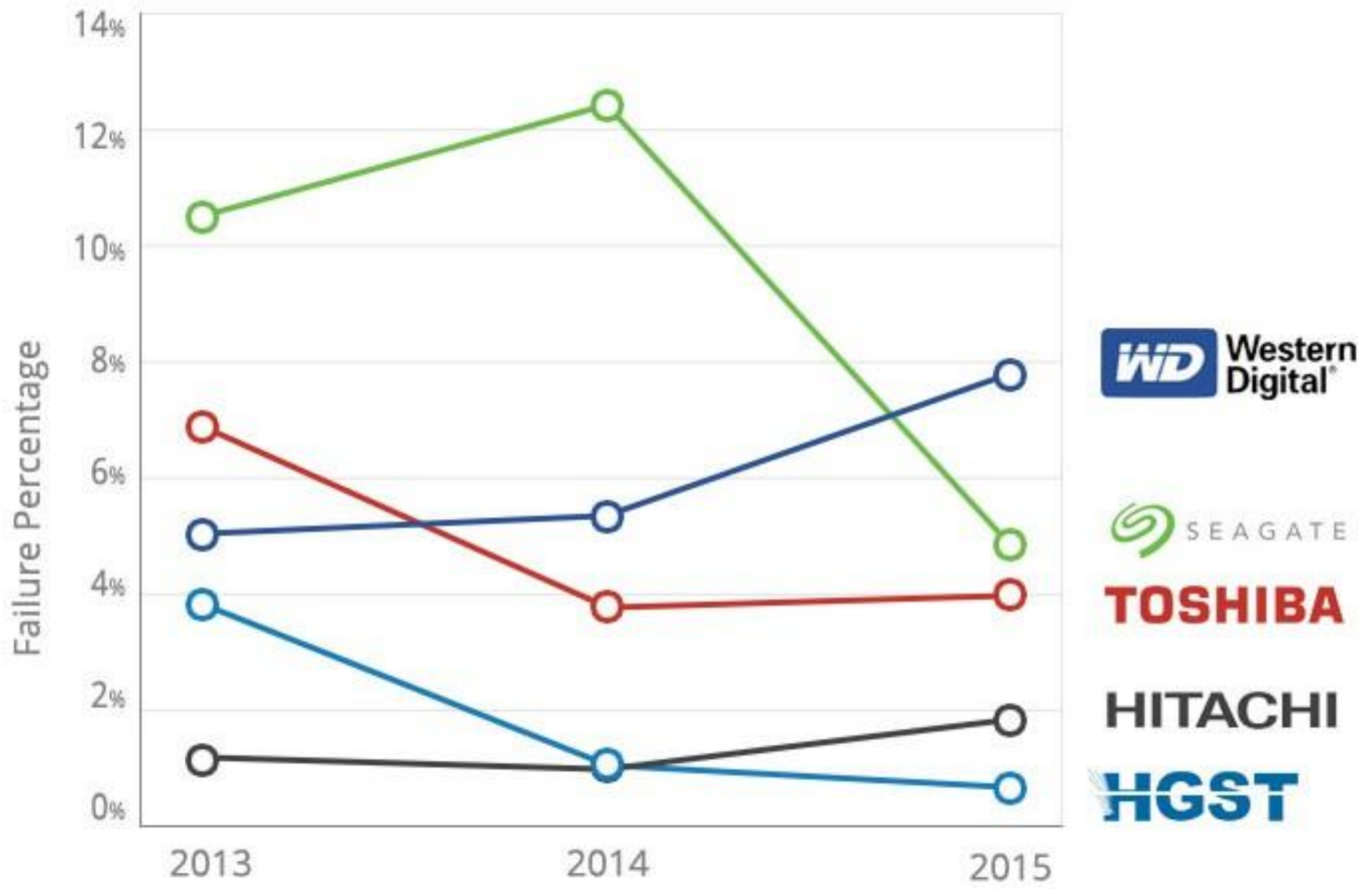
Below is the chart of failure percentages by manufacturer. This is for all the drives in this analysis for the years noted:




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## by Manufacturer

(Year 2013-2015)



Embed this graph on your site

```

<a href="https://www.backblaze.com/blog/hard-drive-reliability-q3-
```

## Our Environment





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we pull the available SMART stats reported by each and every drive. These stats are available for download from our [Hard Drive Data](#) web page. Those stats form the basis for this blog post. The large data files make for large data sets to work on, but if you give it a try, please let us know if you find anything interesting.

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## Andy Klein

Director of Product Marketing at [Backblaze](#)

Andy has 20+ years experience in technology marketing. He has shared his expertise in computer security and data backup at the Federal Trade Commission, Rootstech, RSA and over 100 other events. His current passion is to get everyone to back up their data before it's too late.

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**frogstein** • 3 years ago

Would nice to see a graph of failure rate vs. age for each model, rather than just year of failure. Percent failures per year doesn't tell me how old each drive was when it failed.

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**Andy Klein** Mod → **frogstein** • 3 years ago



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I'm a reliability engineer by trade, and ideally, what you want to do is express the data as a reliability or survival number with respect to time. The appropriate way to do this is through a Weibull distribution.

I've taken the data up through Q2 (haven't done the Q3 data) and processed it to put all the failures and suspensions together for the individual hard drive models and then created a Weibull distribution for 11 of the most used hard drives listed above. This provides a probabilistic basis for assessing future failures of your different hard types. I've posted a picture of the resulting models plotted of Reliability (1 = 100% of the units will have survived) vs Time (if the link below works). For instance, for HDS723030ALA640, at 25000 hrs, we would expect 97.8% to have survived (2.2% failure rate).

As commented elsewhere, this is a much better way of expressing the expected reliability as a function of hours of operation, rather than annualized failure rate, as this will take into consideration the "infant mortality" effects, and "wear out" effects of the data, and actually predict them.

Interestingly, the data seems to group itself - that is the models for the Western

[see more](#)

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**Adrian Kelly** ➔ Paul Biedler • 3 years ago

Thank you for doing this work! These kind of survival rate vs time graphs are exactly what Backblaze should be publishing, or at the very least failure rates at different time intervals. They have a huge amount of data at their disposal and it could be so much more useful.

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**calmdownbro** ➔ Paul Biedler • 3 years ago

Well, the data is available for free of charge. Grab it, do it, share it.

2 • Reply • Share ›



**David Fickes** ➔ Paul Biedler • 3 years ago

I'm wondering if it should be a Weibull distribution at all. I took all of the failures together for 2015 and then ran an input analysis which suggested that a Beta function was a better fit. I've thought of going through each of the drive models and running the same input analysis for each drive.

Any suggestions?

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**Paul Biedler** ➔ David Fickes • 3 years ago



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work as well.

Grouping all the failures across models together would be very unlikely to get a good distribution fit, because the underlying characteristics for each of the drives would be different. In addition, the various drive brands themselves are not of any particular distribution, so the failures of different brands are going to weight differently, which is going to skew things terribly - recently happened to me on a sensor analysis I was doing, until I realized what was going on. No, you'd have to go through each of the drive models, which is what I've done here, although I need to update through Q4 when it comes out.

2 ^ | v • Reply • Share ›



**David Talaga** → David Fickes • 3 years ago

The Weibull distribution is not at all consistent with the empirical distribution of survival. <https://www.backblaze.com/b...>

The Weibull distribution assumes a unimodal distribution of failure rates. The data suggests a trimodal distribution of failure rates. Moreover it also suggests that there are different classes of failure with different rate behaviors. That is not consistent with the Weibull picture.

So, I disagree. The Weibull distribution is not at all appropriate to model this data.

I would probably model the failure using a set of coupled kinetic equations that account for the 3 modes of failure. I think it would be difficult to capture the phenomenon with fewer than 4 parameters. One parameter would capture the fraction of units subject to infant mortality. Another parameter would capture the baseline rate of failure. Another parameter would capture the accumulation of wear resulting in wear-out failures. You'd probably one or two more parameters to handle the relative time scales and proportions.

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**Dave Grodzki** → Paul Biedler • 2 years ago

Small world Paul... Stumbled upon this article looking into some reliability for a drive I use in my NAS, and saw your comment. Your plot is very useful.

^ | v • Reply • Share ›



**Junky** → frogstein • 3 years ago

also, vs IOs or data transfer measure of some kind

^ | v • Reply • Share ›



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experiences. (I have nearly 50 hard drives right now... who knows how many over the years... )  
But really, this is just a thank you for continuing with these reports. I appreciate it.

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**YevP** Mod [Tracy Valteau](#) • 3 years ago

Our pleasure Tracy! We're glad you like the posts! Thanks for reading :)

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**Joshua Kugler** • 3 years ago

Can you explain the failure rates over 100%? The Seagate Barracuda Green drives.

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**Jason Hall** [Joshua Kugler](#) • 3 years ago

drive fails in under a year, is replaced, that drive fails under a year too, %200 failure rate...

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**YevP** Mod [Joshua Kugler](#) • 3 years ago

It's an annualized failure rate, so if a lot of the units fail in less than a year, it'll be a higher failure rate.

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**andrewc2** • 3 years ago

Wow talk about timing, I was just reading the post from last year and thought man I hope they do another of these, and boom there it is. Thanks!

5 • [Reply](#) • [Share](#) ›



**Frank Bulk** • 3 years ago

It appears that the combination of larger drives with lower failure rates result in a significantly lower failure rate per bit!

At what point is there a tradeoff between cost and failure rate? If the drive \$10 more but has a 1% lower failure rate, is that "worth" it?

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**Andy Klein** Mod [Frank Bulk](#) • 3 years ago

The trade-off between failure rate and cost is something we consider here, but there are many variables in play, especially in our environment and how our software operates. We are looking at writing a post to look at this topic to examine these variables and see where that trade-off point lies.

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**timothvhooD** • 3 years ago



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since. The remaining Seagate drives were used for migrating data and other occasional use, with only one drive left alive. I would never buy a Seagate again, and I would never use one even if given it for free unless I was 100% confident in my backup solution (which certainly would not involve Seagate drives).

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**Nick** → timothyhood • 3 years ago

What strikes me as hilarious is your switch to HGST, as they gave us what was quite likely the least reliable hard drive of all time, the IBM Deskstar 75GXP, aka Deathstars.

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**timothyhood** → Nick • 3 years ago

Probably because that was 15 years ago, which is 10 generations in the computer world. Kind of like blaming a family's problems on their great-great-great-great-great-great grandfather. Also, that was one model, whereas Seagate has had reliability issues with many, many models over a consistent and longer time period. No manufacturer is perfect, but you can at least go with the odds.

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**Soldier** → Nick • 3 years ago

lol, holding on to a grudge for 15 years. The point is that they make reliable hard drives now and HGST brands are offered at a lower price sometimes if you look for deals online. Not only more reliable but cheaper in some cases.

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**phuzz** → timothyhood • 3 years ago

The data shows that \*some models\* of Seagate drives are rubbish, but it also shows that overall there wasn't much between any of the manufacturers.

Of course, there's no easy way to tell that a particular model of drive won't turn out to be a dog until it's been in service for at least six months, so the best advice is, buy the drives with the best warranty/replacement program, and always backup your data.

4 • Reply • Share ›



**calmdownbro** → phuzz • 3 years ago

Had tons of drives in my desktops and laptops, servers, literally all the form factors. One thing was consistent. Seagates die. In desktop, in laptop, and in my servers. I mean yes, it's just some models, but I was damn unlucky to pick all the bad ones.

Since then I use Toshiba, WD, and I never had a single drive failure. None, zero. I only threw out drives that were too old/too small, but they worked perfectly fine until the last minute.

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purchase with light usage. No more WD for me! I bought 4 of them before I learned my lesson. :(

And yeah, Seagates are terrible too in general. I see lots of failed Seagate drives at work.

^ | v • Reply • Share ›



**Craig Herring** → phuzz • 3 years ago

Completely agree with this response. Been in the industry for 25 years and have seen all sorts of issues. Interesting study shows that IT people ARE the reason for data disasters 43% of the time. All hardware will fail at some point, the industry designs it to fail or else there's no industry. Microsoft's latest OS is always the "best". These are interesting studies and have some value especially evaluating scalability and FUD de-validation. If you backup your data you will never loose it because of a dead drive regardless of brand.

^ | v • Reply • Share ›



**timothyhood** → Craig Herring • 3 years ago

Sure, back up your data to prevent loss, but what about the cost of having to restore data and replace dead drives? Isn't it best to try to get the most reliable storage in the first place? And if one brand seems to have double the lemon rate, wouldn't it make sense to avoid that brand and not take the risk?

2 ^ | v • Reply • Share ›



**Xebozone** → Craig Herring • 3 years ago

What about Windows ME, Visa, 8.0... not the best :)

Microsoft has a trend that I realized of Good/Bad/Good OSes...

But now that W10 is the 'last one'... we will see how things change.

^ | v • Reply • Share ›



**vorpaladin** → Xebozone • 3 years ago

I believe his point is that MS always claims the newest OS is the best, when of course all of them are terrible. Although XP and Win7 get honorable mentions.

3 ^ | v • Reply • Share ›



**galan** → timothyhood • 2 years ago

In the past 15 years I've owned dozens of Seagate and Western Digital drives. I've had numerous failures from both. I don't love one brand more than the other. I recently had a 2tb WD Green drive die after about 5 years, but I still have some Seagate 250gig drives that I've had since 2004-2006 that still work perfectly well. The 7200.11 series drives from Seagate were awful, and they sullied Seagate's reputation, but their other drives haven't





**Steve Irons** • 3 years ago

Any idea when the 4th quarter result will be up? I got burned really badly on the 3TB Seagates, and have several of them on ice until I can transfer the contents to more dependable drives.

2 ^ | v • Reply • Share ›



**Max** ➔ Steve Irons • 2 years ago

lol savage baby from mad max2

^ | v • Reply • Share ›



**Kyle** • 3 years ago

Whatever happened to those 8TB SMR drives you said you would try? It's been at least 6 months.

2 ^ | v • Reply • Share ›



**Andy Klein** Mod ➔ Kyle • 3 years ago

They ended up in the engineering lab, I don't have anything to report yet.

3 ^ | v • Reply • Share ›



**Jus' Sayin'** • a year ago

I ran across an impressive second take on Backblaze's data.

Kudos and thanks to both Backblaze and the scientist.

<https://bioinformare.blogspot...>

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**Chris Butler** • 3 years ago

What a phenomenally useful quarterly post. Thank you!

I am about to replace 8 SATA desktop class drives in 8 High-Rely removable drive carriers that we use with our Tandem DXR dual bay removable storage system. They are used every night in a rotation of supplemental full backups that are taken to a secure offsite facility

Up until I found this blog, I dreaded the idea of researching hard drive reliability based on "reviews" which usually boils down to either first day performance comparisons, or amazon / newegg / etc "reviews" which are usually only written by people who have a defective product, or are angry with the online retailer's handling of the purchase.

Only your unique environment could really give useful data to a hard drive market segment that is by nature usually small-scale in real world situations.

Thank you so much, this really likely will save us many headaches years down the road.

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maybe you use 10,000 Seagate drives and 100,000 HP drives, so Seagate would have bigger failure rate than HGST.

Any information about that? Otherwise these rates don't seem objective to me.

1 ^ | v • Reply • Share ›



**Ben Jolly** → External HDD • 3 years ago

see the field "max # in service"

otherwise, as stated at the end of the article, they release this information in its raw data for you to process anyway you please.

<https://www.backblaze.com/h...>

^ | v • Reply • Share ›



**Matthew F** • 3 years ago

Funny as before with their flawed study... they claimed Seagate was the worst... and yet, here they are,. they keep buying Seagate drives...

2 ^ | v • Reply • Share ›



**fencepost** → Matthew F • 3 years ago

There's some discussion of drive prices in an earlier post. At that time, the HGST drives were both more reliable and 30+% more expensive, so they can work with the cheaper drives (and get warranty replacements for them unless they're lingering "shucked" ones) and still have the total cost be lower than using the more expensive higher-reliability drives.

Backblaze has good redundancy in place and a simple and efficient system for replacing drives. They can tolerate failures that would be a much bigger problem in smaller setups.

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**HenkPoley** → Matthew F • 3 years ago

For their purpose it's not worse enough to switch. If you have many copies laying around, the fact that there is an 0.04% chance that a drive dies this day is not substantial (with ~13.5% annual rate). You'll just recover from any of the other copies.

And actually numbers are better than the ones I used above.

1 ^ | v • Reply • Share ›



**Drashna** • 3 years ago

It's nice to see statistics that mean ABSOLUTELY NOTHING.

Seriously, any comparison is apples and oranges. You use WD Reds for the WD almost exclusively, but you use Seagate LP (aka green) and desktop drives for all the seagate drives. Different work loads, different behavior.

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**Milk Manson** His Shadow • 3 years ago

You sure it's not the same guy?

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**timmmay** Milk Manson • 3 years ago

It's important he read the headline that says "Drives that work best FOR US" not as Drives that work best FOR YOU.

These graphs reflect one use case scenario for these drives: bulk sequential data collection - cold storage.

Any desktop PC is going to have lots of random IO, lots of power cycles and lots of head parking.

Look at the graphs for what they are. DO NOT MISINTERPRETE THEM. In reality, hard disks across the board have similar failure rates, although it's hard to argue with Hitachi's low failure rate. I've seen one fail in like 7 years.

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**Milk Manson** timmmay • 3 years ago

Timmmay Timmmay Timmmay, you're preaching to the choir.

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**Matthew F** His Shadow • 3 years ago

"Green" Drives are not meant for the usage backblaze is using them for..that is why he is "that guy" there also seemed to be some flaws on their last test results as well>

<http://www.enterprisestorag...>

and

<http://www.tweaktown.com/ar...>

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**David Fickes** Drashna • 3 years ago

I believe these stats are absolutely useful as long as you realize what you are comparing.

Backblaze is the only vendor sharing this data with anyone. Google/Facebook/Yahoo all have their own data and keep it to themselves for the most part. Yes, the builds of the WD Reds and Seagate LP are different and that might account for some of the failure rate differences.

The main difference and possible error in extrapolating "global" conclusions is the



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**Drashna**

David Fickes • 3 years ago

And statistics on 45 drives is statistically insignificant.

And it's entirely a marketing/publicity stunt (repeatedly), because they're the only ones doing it still. And why don't Seagate and WDC release info? Because they don't want people to draw false conclusions... which is what happens every time BackBlaze releases one of these reports.

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**Milk Manson** → Drashna • 3 years ago

Because they don't want people to draw false conclusions? No, it's because they don't want people drawing ANY conclusions. Screw that.

8 ^ | v • Reply • Share ›

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**Matthew F** — Do not use raid 5 with large drives, you are asking for a flip bit and failure and likely a 2nd failure on rebuild. Raid 10 or

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